Chapter 3: Booadcasting, Multicasting, and Geocasting

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Routing Protocols

Topology-Based:
Depends on the information about existing links

- Position-Based Approaches
- Proactive (or table-driven)
  - Proactive (Table-driven) protocols
  - Traditional distributed shortest-path protocols
  - Maintain routes between every host pair at all times
  - Based on periodic updates; High routing overhead
  - Example: DSDV (destination sequenced distance vector)
- Reactive (On-Demand) protocols
  - Determine route if and when needed
  - Source initiates route discovery
  - Example: DSR (dynamic source routing)
- Hybrid protocols
  - Adaptive: Combination of proactive and reactive
  - Example: ZRP (zone routing protocol)

Routing Approaches

- Broadcasting
  - Is a common operation in many applications, e.g., graph-related and distributed computing problems
  - It is also widely used to resolve many network layer problems
- Multicasting
  - Transmission of datagrams to a group of hosts identified by a single destination address
  - Hence is intended for group-oriented computing
  - Can efficiently support a variety of applications that are characterized by close collaborative efforts
- Geocasting
  - Aims at delivering data packets to a group of nodes located in a specified geographical area
  - Can be seen as a variant of the conventional multicasting problem, and distinguishes itself by specifying hosts as group members within a specified geographical region
- Since all these three do communication to a group of recipients, it is imperative to determine what is the best way to provide these services in an ad hoc (MANET) environment
- Comparison of broadcast, multicast and geocast protocols for ad hoc networks provided

The Broadcast Storm

- MANET consists of a set of MHs that may communicate with one another from time to time
  - No base stations are present
  - Each host is equipped with a CSMA/CA
  - Transmission of a message to all other MHs required
- The broadcast is spontaneous
  - Due to MH mobility and lack of synchronization, any kind of global topology knowledge is prohibitive
  - Little or no local information may be collected in advance
- The broadcast is frequently unreliable
  - Acknowledgement mechanism is rarely used
  - Distribute a broadcast message to as many MHs as possible without putting too much effort
  - A MH may miss a broadcast message because it is off-line, it is temporarily isolated from the network, or it experiences repetitive collisions

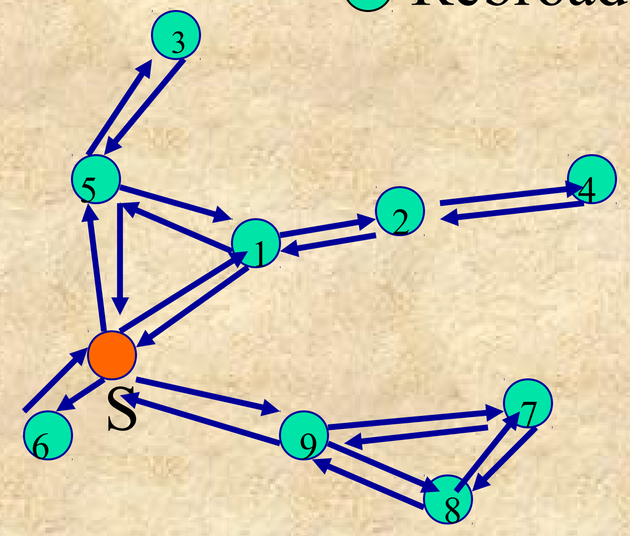
The Broadcast Storm

- Broadcast
  - Acknowledgements may cause serious medium contention
  - In many applications 100% reliable broadcast is unnecessary
  - MH can detect duplicate broadcast messages
  - If flooding is used blindly, many redundant messages will be sent and serious contention/collision will be incurred
- Redundant rebroadcasts
  - When a MH decides to rebroadcast, all its neighbors may already have the message
- Contention
  - Transmissions from neighbors may severely contend with each other
- Collision
  - Due to absence of collision detection, collisions are more likely to occur and cause more damage

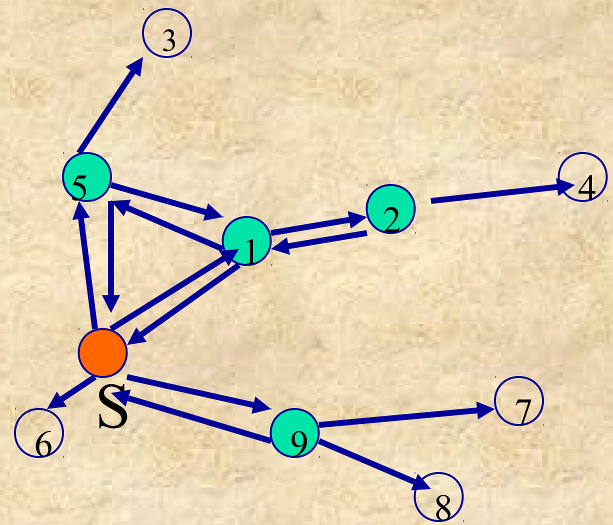
Example (simple flooding)

● Source node

● Rebroadcast node



Better Solution: Only 4 Rebroadcast nodes



1st step: S

2nd step: 1, 5, 6, 9

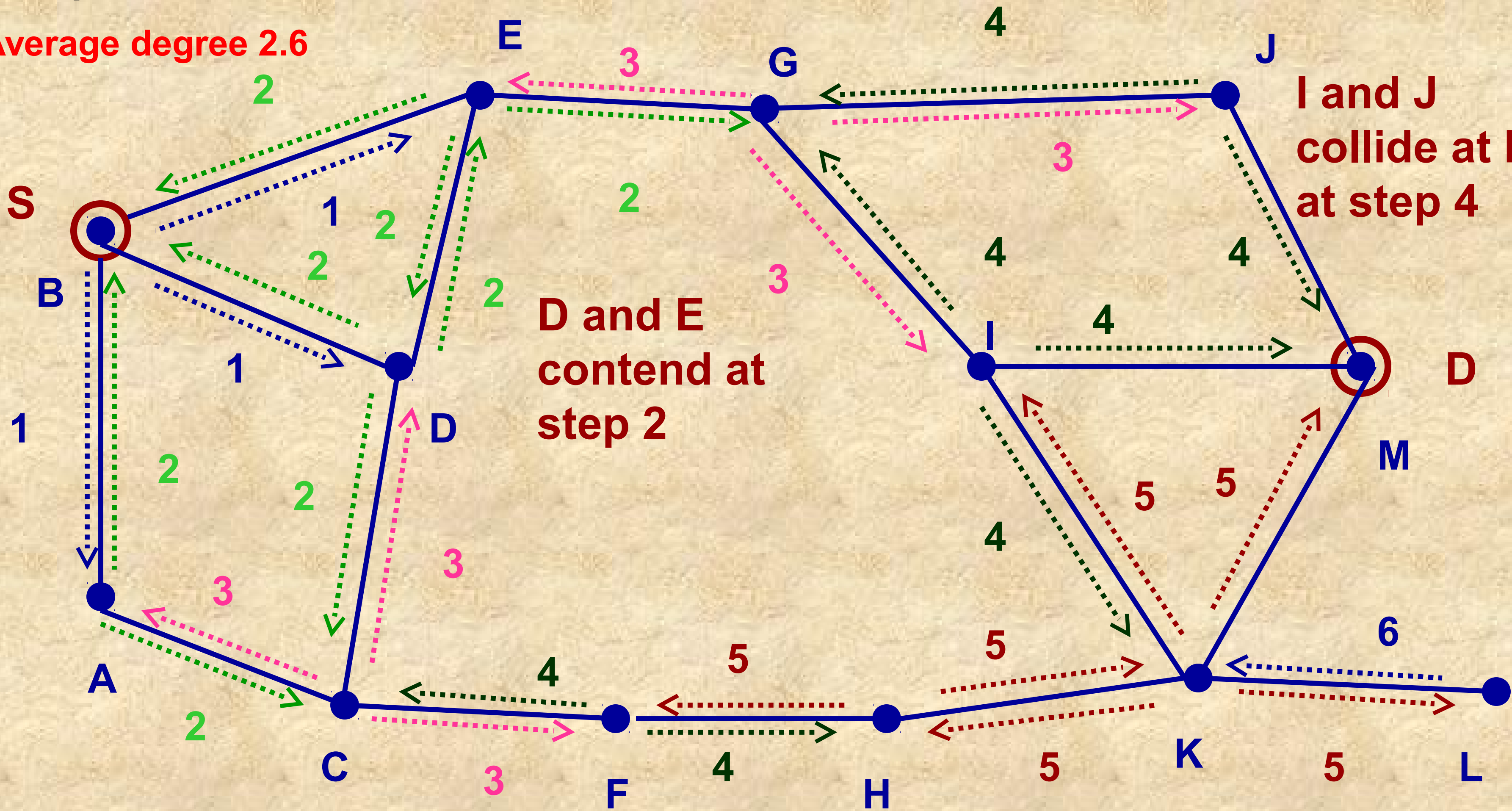
3rd step: 2, 3, 7, 8

4th step: 4

Total: 9 Rebroadcast nodes

Example broadcast storm problem in a 13 node MANET

Average degree 2.6



D and E contend at step 2

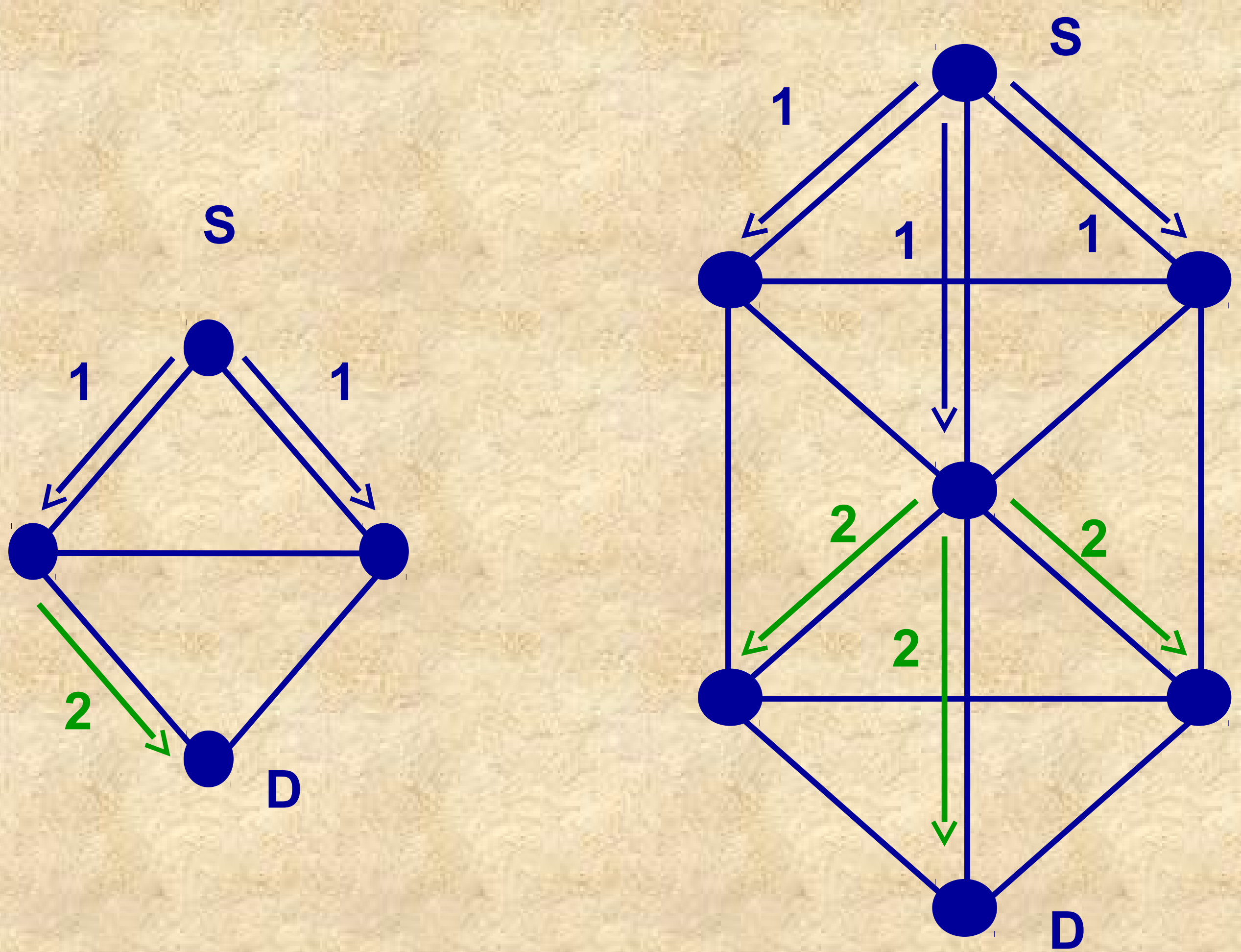
I and J collide at M at step 4

A and D collide at C at step 2

H and K contend at step 5

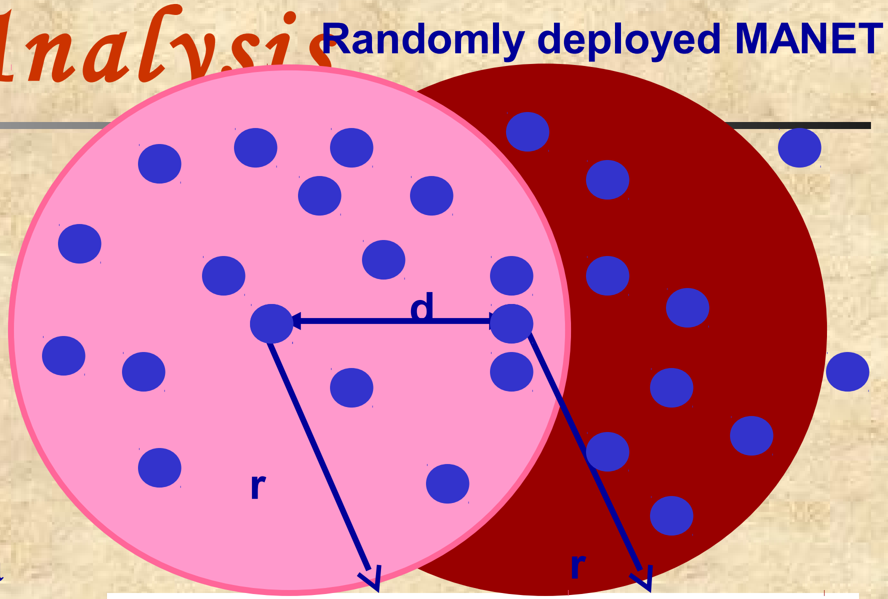
Message still propagates …..

Redundancy Analysis

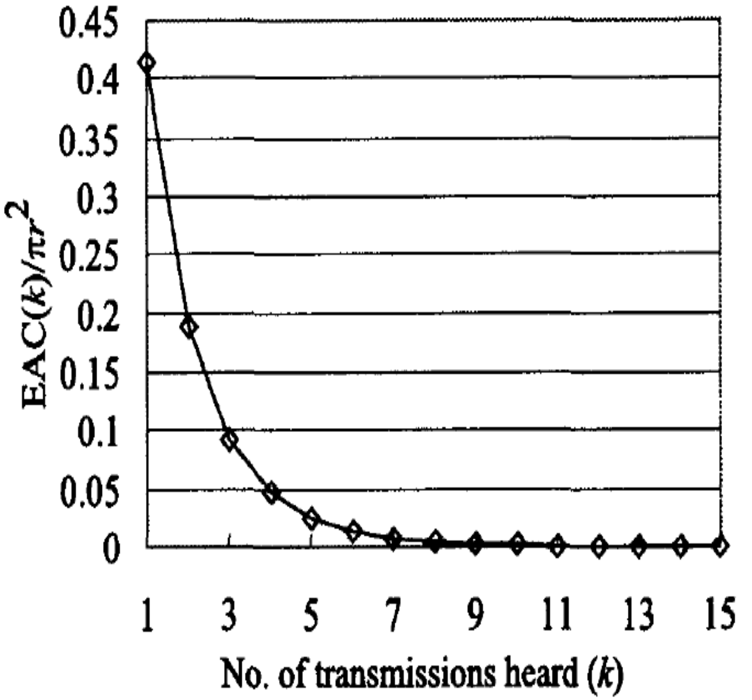


Optimal Broadcast in MANETs

Redundancy Analysis



- Assume that the total area covered by the radio signal transmitted by a transceiver is a circle of radius *r*
- Intersection area of two circles of radio *r* whose centers are d apart be INTC(*d*)
- *Additional coverage* provided by a host to who rebroadcasts the packet is equal to πr^2 – INTC(*d*)
- When $d = r$, the additional coverage is approximately $0.61\pi r^2$ (maximum)
- Average additional coverage by rebroadcasting from randomly located host is $0.41\pi r^2$
- *Expected additional coverage* provided by a host's rebroadcast after the same broadcast packet received by host *k* times is denoted by EAC(*k*)



Rebroadcasting Schemes

- Minimize number of retransmissions of a broadcast message
- Attempt to deliver a broadcast packet to each and every node in the network

Common Attributes of Broadcast Protocols

- Jitter and Random Delay Timer (RDT)
  - Jitter allows one neighbor to acquire the channel first while other neighbors detect that the channel is busy
  - RDT allows a node to keep track of redundant packets received over a short time interval
- Loop Prevention
  - Node rebroadcasts a given packet no more than one time by caching original source node ID of the packet and the packet ID

Categories of Broadcasting Protocols

- Simple flooding
  - A source node broadcasting a packet to all neighbors
  - The neighbors, upon receiving the broadcast packet, rebroadcast the packet exactly once
- Probability-based methods
  - Similar to ordinary flooding
  - Nodes only rebroadcast with a predetermined probability
  - In dense networks, multiple nodes share similar transmission coverage
  - Counter-Based Scheme: relationship between number of times a packet is received and the probability of a node's transmission to cover additional area on a rebroadcast
- Area-based methods
- Neighbor knowledge methods

Categories of Broadcasting Protocols

- Area-based methods
  - If a sender is located only one meter away, the additional area covered by the retransmission by a receiving node rebroadcasts is quite low
  - *Distance-based scheme* compares the distance between itself and each of its neighbor nodes that has previously rebroadcast a given packet
  - *Location-based scheme* uses a more precise estimation of expected additional coverage area
- Neighbor knowledge methods
  - Flooding with Self Pruning requires each node to have knowledge of its one-hop neighbors
  - Scalable Broadcast Algorithm (SBA) requires that all nodes have knowledge of their neighbors within a two-hop radius
  - Each node searches its neighbor tables for the maximum neighbor degree of any neighbor node, say, d_{Nmax}
  - Calculates a Random Time Delay (RDT) based on the ratio of $\left(\frac{d_{N\max}}{d_{me}}\right)$ where d_{me} is the number of current neighbors for the node

Categories of Broadcasting Protocols

- Neighbor knowledge methods…..
  - Dominant Pruning: Uses two-hop neighbor knowledge, but proactively choosing some or all of its one-hop neighbors as rebroadcasting nodes
  - Multipoint Relaying: Similar to Dominant Pruning, but rebroadcasting nodes, [Multipoint Relays (MPRs)] are explicitly chosen by upstream senders

Algorithm for a node to choose its MPRs

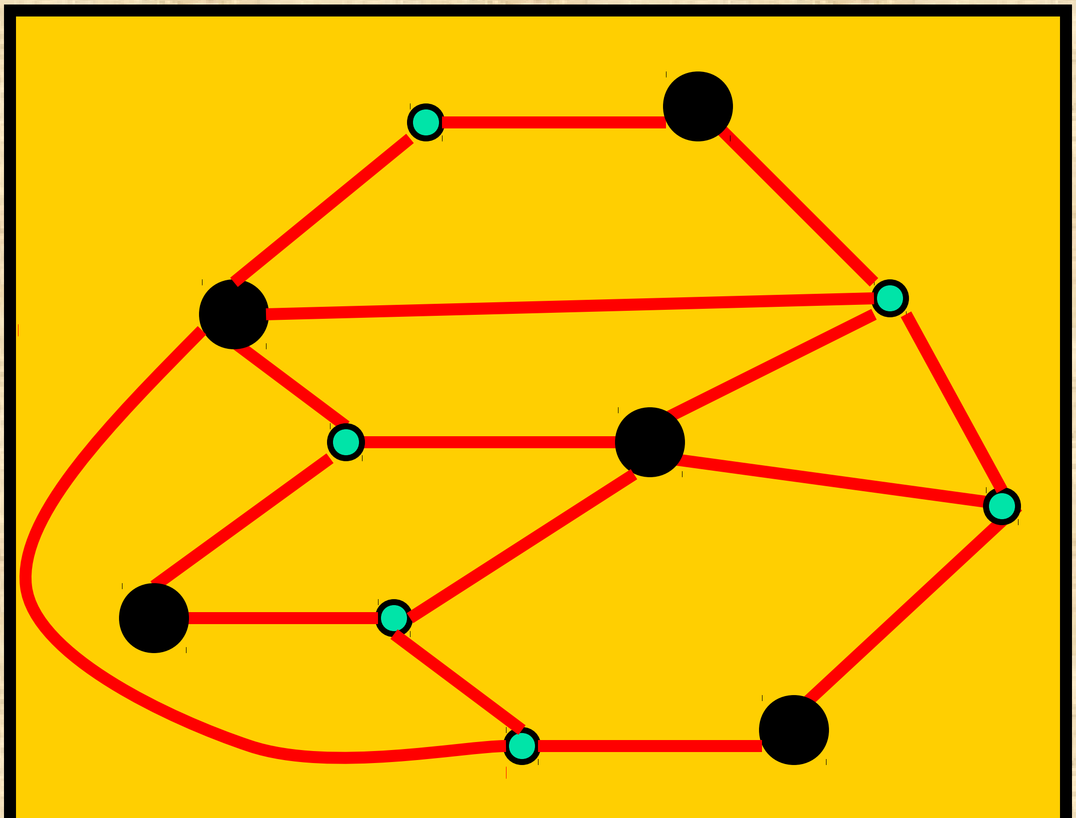
1. Find all two-hop neighbors that can only be reached by one one-hop neighbor and assign those one-hop neighbors as MPRs
2. Determine the resultant cover set (i.e., the set of two-hop neighbors that will receive the packet from the current MPR set)
3. From the remaining one-hop neighbors not yet in the MPR set, find the one that would cover the most two-hop neighbors not in the cover set
4. Repeat from step 2 until all two-hop neighbors are covered

Categories of Broadcasting Protocols

- Ad Hoc Broadcast Protocol (AHBP)
  - Approach similar to Multipoint Relaying by designating nodes as a Broadcast Relay Gateway (BRG)
  - AHBP differs from Multipoint Relaying in three ways:

    1. A node using AHBP informs one-hop neighbors of the BRG designation by a field in the header of each broadcast packet as opposed to done by hello packets in Multipoint Relaying
    2. In AHBP, when a node receives a broadcast packet listed as a BRG, it uses two-hop neighbor knowledge to find which neighbors also received the broadcast packet in the same transmission so as to remove from the neighbor graph
    3. AHBP is extended to account for high mobility networks
- Connected Dominating Set-Based Broadcast Algorithm
  - A dominating set for a graph is a set of vertices whose neighbors, along with themselves, constitute all the vertices in the graph
  - A connected dominating set of minimum size in a graph includes vertices in the dominating set to be connected as well
  - Considers the set of higher priority BRGs selected by the previous sender

Dominated Set

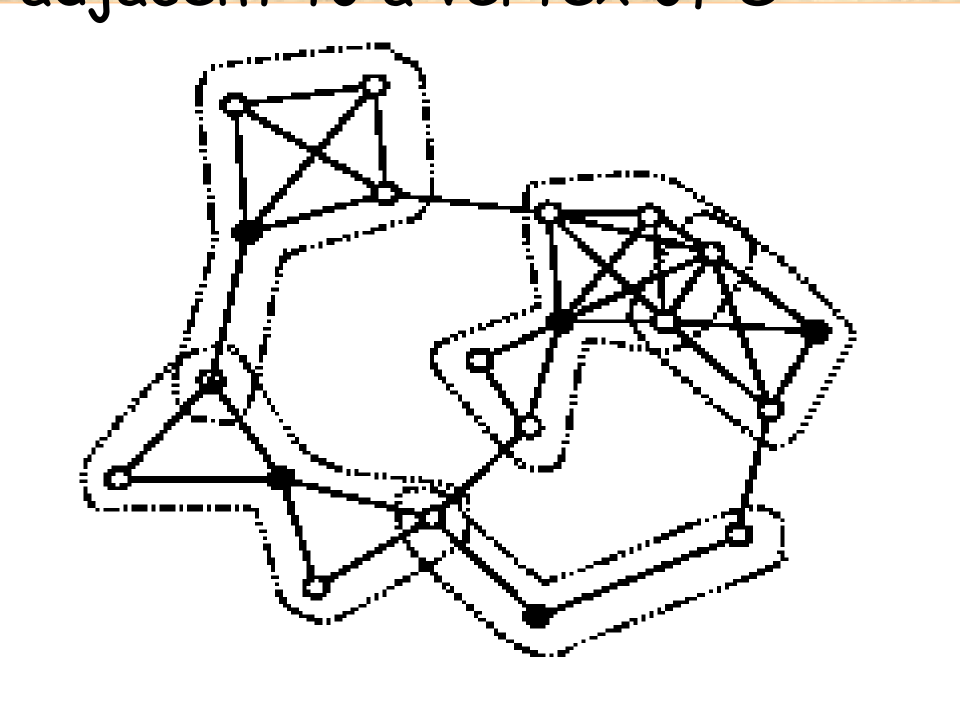


The black vertices are the member of Dominating Set

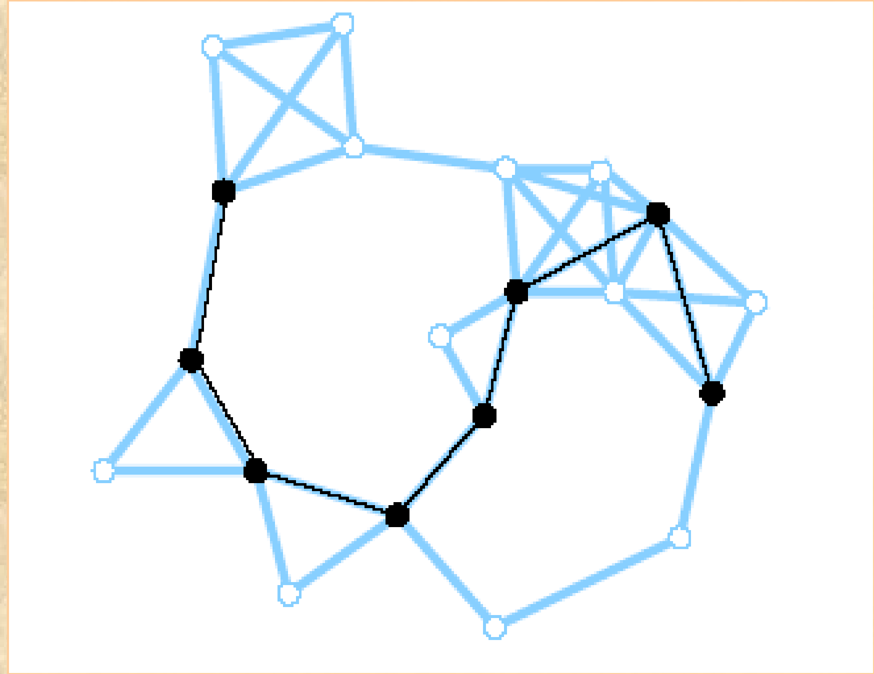
If you allow all members of dominating set to retransmit, all MHs in the network are guaranteed to be covered

Connected Dominating Set

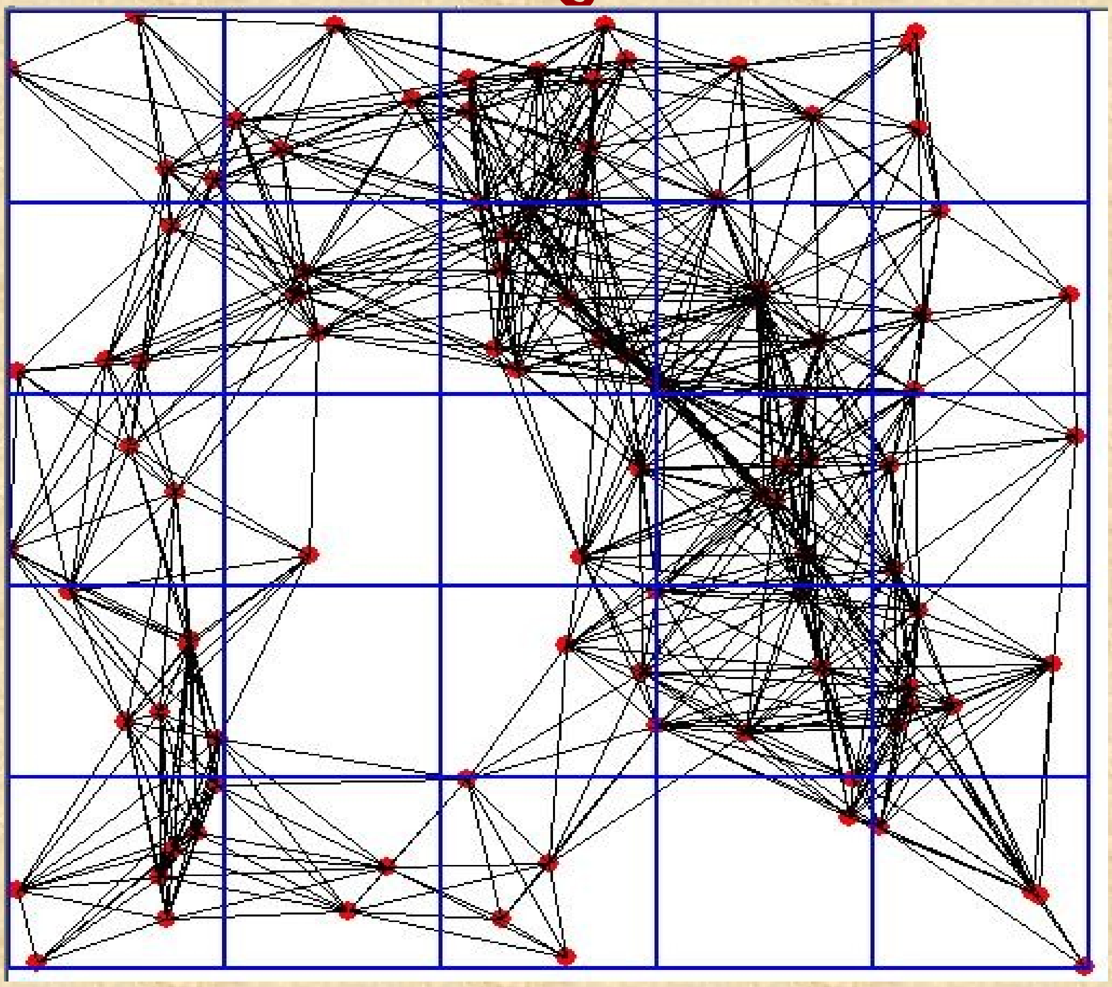
A dominating set of a graph G= (V, E) is a vertex subset S⊆V , such that every vertex v∈V is either in S or adjacent to a vertex of S



A **connected dominating set** **(CDS) of a graph G is a dominating set whose induced graph is connected (this enables any member to be within communication range of another member to enable broadcast)**



Broadcast Nodes in Large Networks?



- Some nodes are highly connected than others
- Similarily, some nodes are sparsely connected than others
- Some nodes are in between
- Dominating Set?
- Complexity?
- Global connectivity knowledge?
- Local knowledge: 2-hop neighbors?
- Some nodes highly connected than other neighbors?
- Some nodes sparsely connected than other neighbors?
- Quantify nodes based on connectivity?

Categories of Broadcasting Protocols

- Connected Dominating Set-Based Broadcast Algorithm - MHs into four groups based on local information as follows:
  - Group 1: Nodes with degrees larger than the degree of all neighboring nodes, where connectivity represents the number of neighbors within the directed transmitting range of a reference node
  - Group 2: Nodes have a majority of neighbors with smaller degree than the reference nodes
  - Group 3: Remaining nodes not belonging to groups 1, 2 and 4
  - Group 4: Nodes with degrees smaller than all the neighbors
  - A message forwarder is assigned in a decreasing probability order as p_1, p_2, p_3 and p_4

Connected Dominating Set-Based Broadcast Algorithm

- **If A be the area of the MANET**
- **N be the number of mobile nodes**
- **r be the communication range of each mobile node with a being the fraction of the area covered and α being the fraction of area covered, then**

$$\alpha = \frac{\pi r^2}{A}$$

- **The average number of neighboring nodes $N_{neighbors}$ can be given by**

$$N_{neighbors} = (N-1)\alpha$$

- **The probability p_i that a mobile node has *i* neighbors, can be given by**

$$p_i = \binom{N-1}{i}(1-\alpha)^{N-1-i}\alpha^i$$

- **The probability p_1, p_2, p_3, and p_4 can be given by**

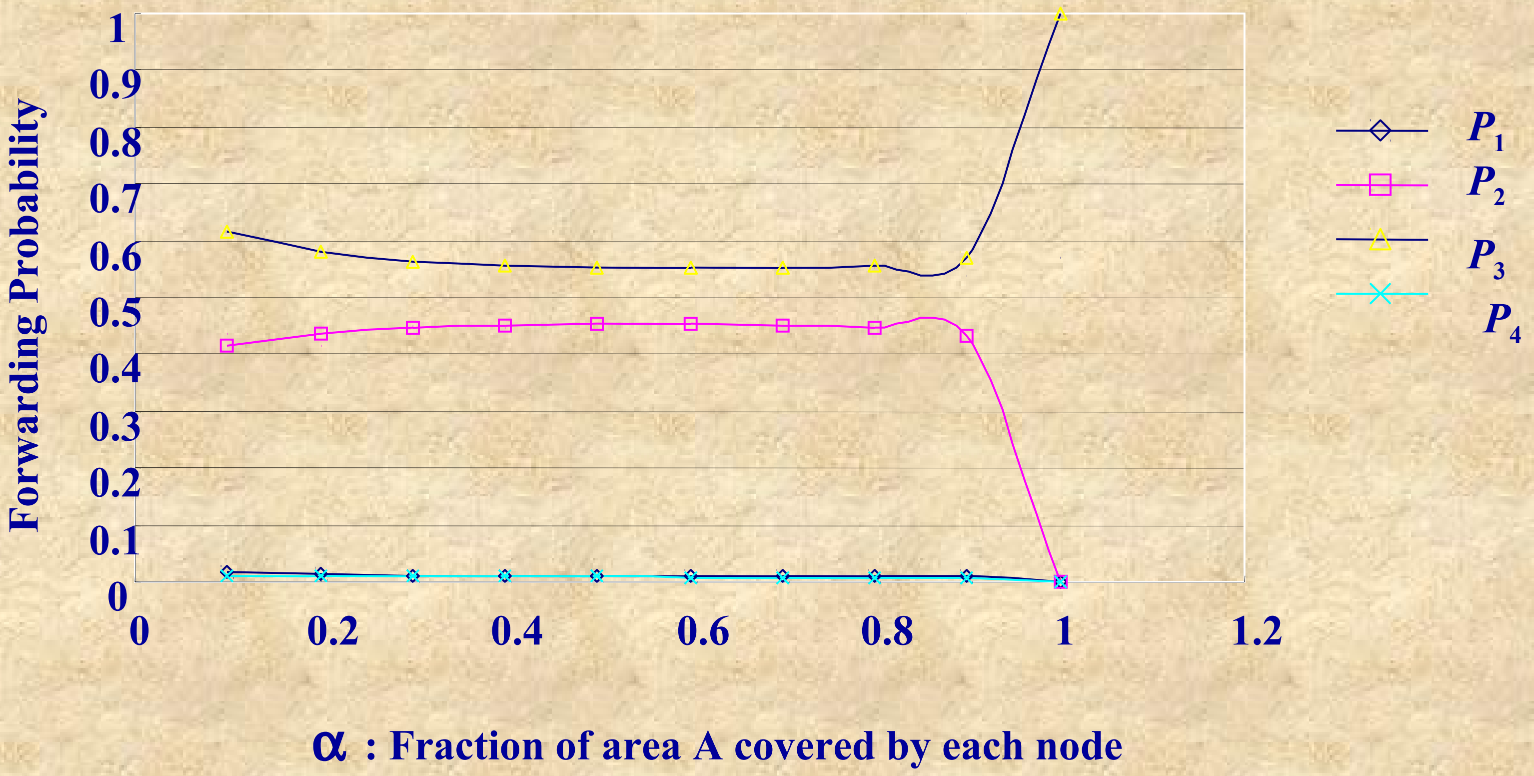
$$P_1 = \sum_{i=1}^{N-1} p_i \binom{N-1}{i}\left(\sum_{j=1}^{i-1} p_j\right)^i \left(1-\sum_{j=1}^{i-1} p_j\right)^{N-1-i}$$

$$P_2 = \sum_{i=1}^{N-1} p_i \left(\sum_{k=1}^{i/2}\left(\binom{i}{k}\left(\sum_{j=i}^{N-1} p_j\right)^k \left(\sum_{j=1}^{i-1} p_j\right)^{i-k}\right)\right)$$

$$P_3 = \sum_{i=1}^{N-1} p_i \left(\sum_{k=i/2}^{i}\left(\binom{i}{k}\left(\sum_{j=i}^{N-1} p_j\right)^k \left(\sum_{j=1}^{i-1} p_j\right)^{i-k}\right)\right)$$

$$P_4 = \sum_{i=1}^{N-1} p_i \binom{N-1}{i}\left(\sum_{j=i+1}^{N-1} p_j\right)^i \left(1-\sum_{j=i+1}^{N-1} p_j\right)^{N-1-i}$$

Group Forwarding Probabilities for N=100



Connected Dominating Set-Based Broadcast Algorithm

- **Total number of forwarding steps, NF :**

$$N_F = N\left(\tau_1 P_1 + \tau_2 P_2 + \tau_3 P_3 + \tau_4 P_4\right)$$

where τ_i is the forwarding probability for the mobile node in group

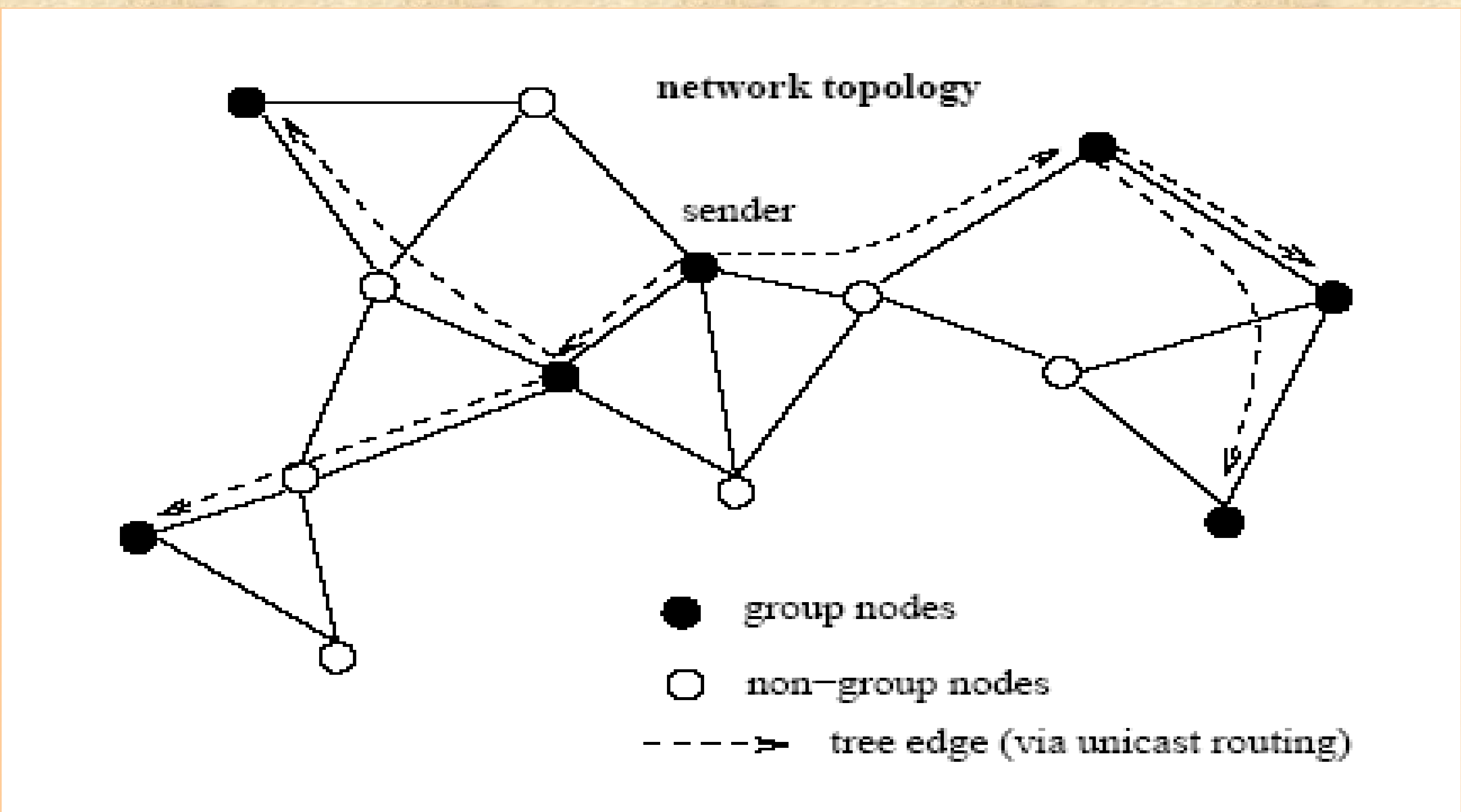
- **Such a scheme does not provide 100% coverage of all MANET nodes**
- **A good coverage and excellent saving are achieved under mobility and about 20% higher goodput is obtained than the conventional AODV**

- **Lightweight and Efficient Network-Wide Broadcast: Relies on two-hop neighbor knowledge obtained from hello packets; however instead of a node explicitly choosing other nodes to rebroadcast, the decision is implicit**

Lightweight and Efficient Network-Wide Broadcast

- Relies on two-hop neighbor knowledge obtained from hello packets
- Each node decides to rebroadcast based on knowledge of which of its other one and two-hop neighbors are expected to rebroadcast
- Knowledge of which neighbors have received a packet from the same source node, and which neighbors have a higher priority for rebroadcasting
- The priority is proportional to the number of neighbors of a given node
- The higher a node's degree is, the higher is its priority

Multicasting v/s Broadcastng?



Multicasting

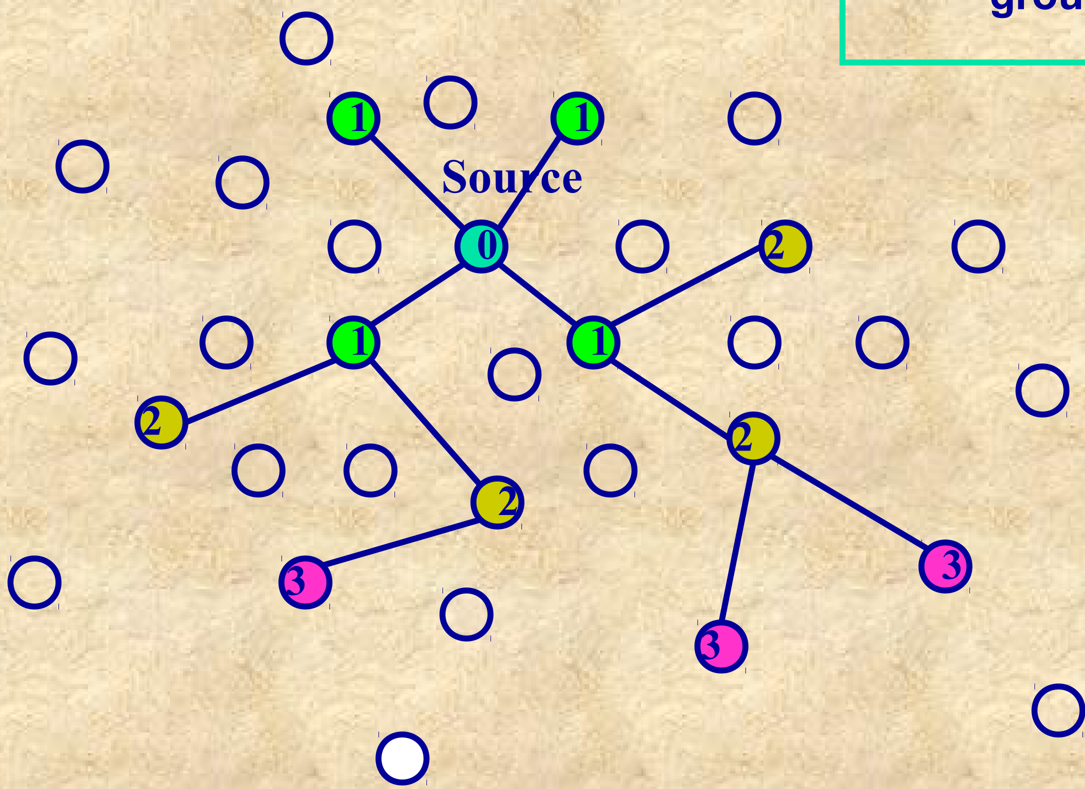
- Routing protocols offering efficient multicasting in wired networks may fail to keep up with node movements and frequent topological changes
- Broadcast protocols cannot be used either as multicasting requires a selected set of nodes to receive the message
- All multicast algorithm depend on the topology of the network
- Majority of applications requiring rapid deployment and dynamic reconfiguration, need multicasting such as military battlefields, emergency search and rescue sites, classrooms, and conventions
- Crucial to reduce the transmission overhead and power consumption
- Multicasting in a MANET faces challenges such as dynamic group membership and update of delivery path due to MH movement

Multicast Routing Protocols

- **Broadcast protocols cannot be used as multicasting requires a selected set of MHs to receive the message**
- **Protocols are classified into four categories based on how route to the members of the group is created:**
  - **Tree-Based Approaches**
  - **Meshed-Based Approaches**
  - **Stateless Multicast**
  - **Hybrid Approaches**

Illustration of Tree-Based Multicast

Nodes not a part of Multicast group



Tree-Based Approaches

- Extend tree-based approach to provide multicast in a MANET
- A packet traverses each hop and node in a tree at most once
- Very simple routing decisions at each node
- Tree structure built representing shortest paths amongst nodes, and a loop-free data distribution structure
- Even a link failure could mean reconfiguration of entire tree structure, could be a major drawback
- Consider either a shared tree or establish a separate tree per each source
  - For separate source trees, each router in multiple router groups must maintain a list of pertinent information for each group and such management per router is inefficient and not scalable
  - For shared trees, there is a potential that packets may not only not traverse shorter paths, but routed on paths with much longer distances

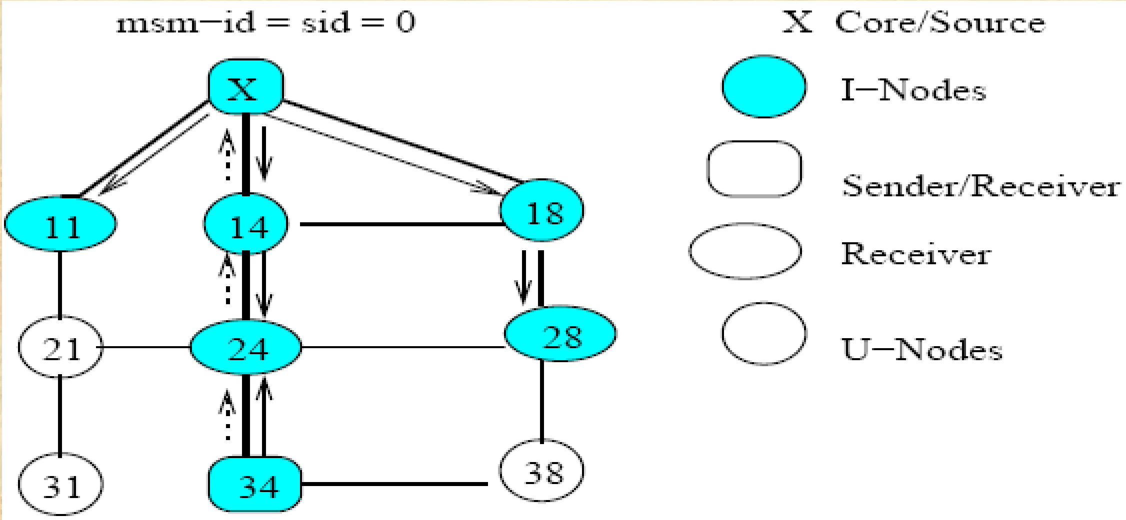
Tree-Based Approaches

Ad hoc Multicast Routing Protocol Utilizing Increasing Id-Numbers

- Utilizing Increasing id-numberS (AMRIS) is an on-demand protocol, which constructs a shared multicast delivery tree to support multiple senders and receivers in a multicast session
- AMRIS dynamically assigns an id-number to each node in each multicast session and a multicast delivery tree – rooted at a special node with Sid (Smallest-ID and is usually a source that initiates a multicast session) – is created and the id-number increases as the tree expands from the Sid
- In case of multiple senders, a Sid is selected among the given set of senders
- Once a Sid is identified, it sends a NEW-SESSION message to its neighbors
- This message includes Sid's msm-id (multicast session member id) and the routing metrics
- Nodes receiving the NEW-SESSION message generate their own msm-ids, which is larger than the msm-id of the sender
- In case a node receives multiple NEW-SESSION messages from different nodes, it keeps the message with the best routing metrics and calculates its msm-ids
- To join an ongoing session, a node checks the NEW-SESSION message, determines a parent with smallest msm-ids, and unicast a JOIN-REQ to its potential parent node
- If parent node is already in the multicast delivery tree, it replies with a JOIN-ACK.
- If a node is unable to find any potential parent node, it executes a branch reconstruction (BR) process to rejoin the tree

Tree-Based Approaches

- *Ad hoc Multicast Routing Protocol Utilizing Increasing Id-Numbers (AMRIS)*
  - **Packet forwarding example**



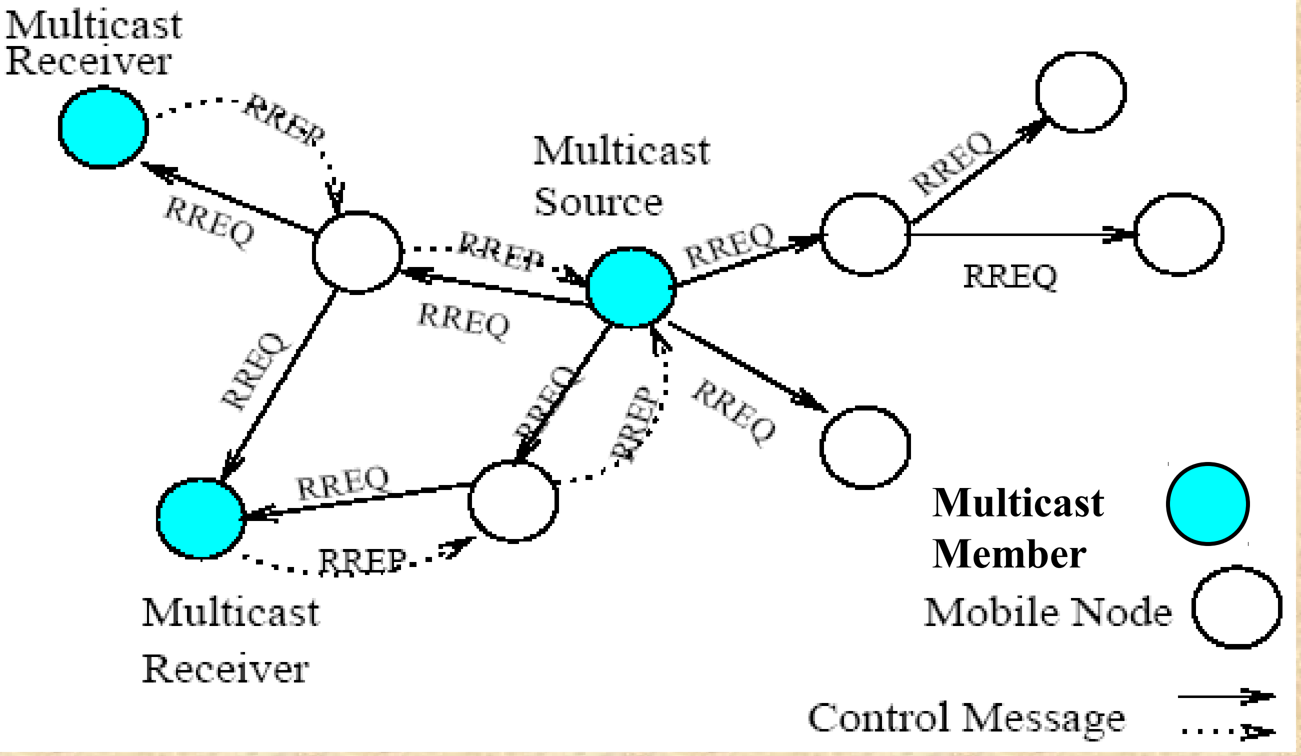
- **Nodes X and 34 are sources**
- **Nodes 11, 24, and 28 are recipients**

Route Discovery and Join for Multicast

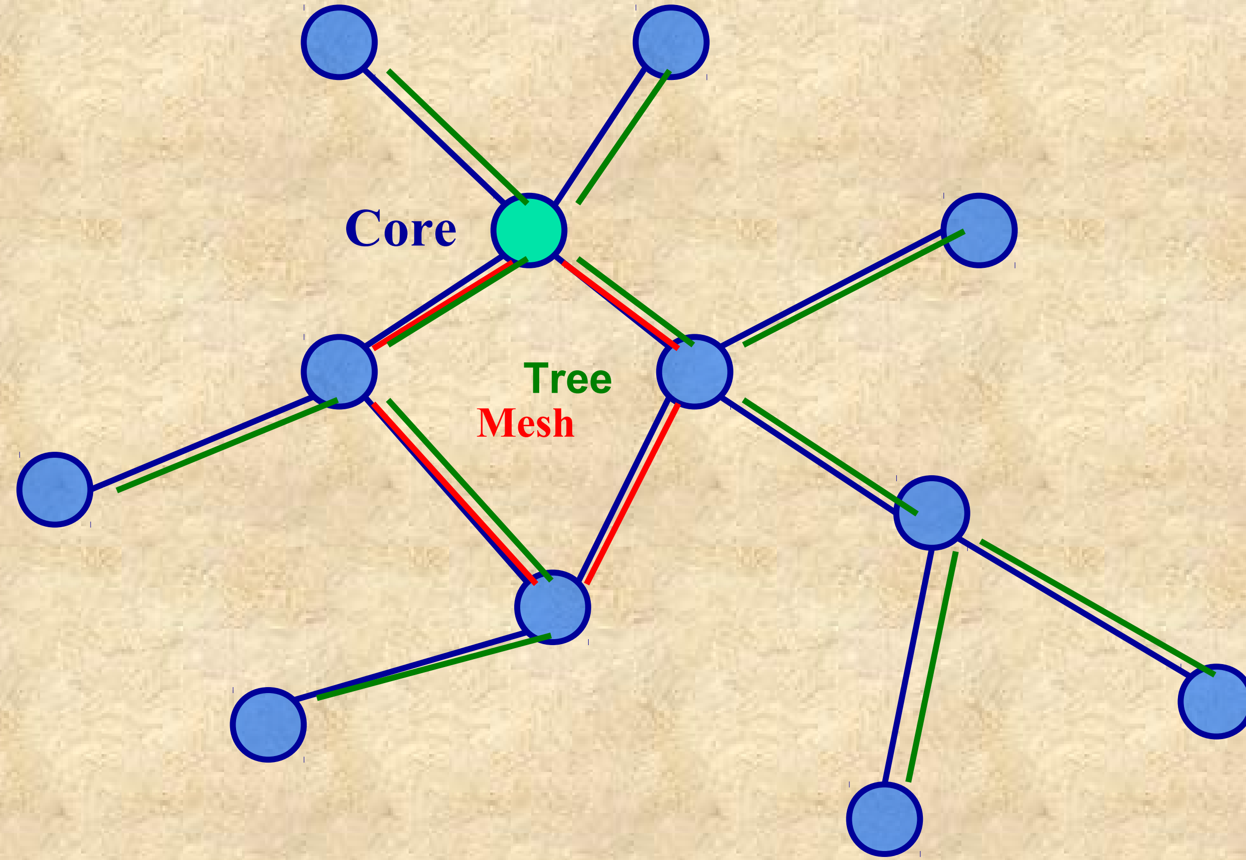
- Multicast Ad hoc On-Demand Distance Vector Protocol
  - Follows directly from the unicast AODV
  - Discovers multicast routes on-demand using a broadcast route discovery mechanism employing the same Route Request (RREQ) and Route Reply (RREP) messages
  - A MH originates a RREQ message when it wishes to join a multicast group, or when it has data to send to a multicast group but it does not have a route to that group
  - Only a member of the desired multicast group may respond to a join RREQ
  - If the RREQ is not a join request, any node with a fresh enough route to the multicast group may respond
  - As the RREQ is broadcasted across the network, nodes set up pointers to establish the reverse route in their route tables
  - A node receiving a RREQ first, updates its route table to record the sequence number
  - For join RREQs, an additional entry is added to the multicast route table and is not activated unless the route is selected to be a part of the multicast tree

Multicast AODV

- **Multicast Ad hoc On-Demand Distance Vector Protocol**
  - **Follows directly from the unicast AODV**



Core Node Selection and Multicast Routing Protocol



Core-Based Approaches

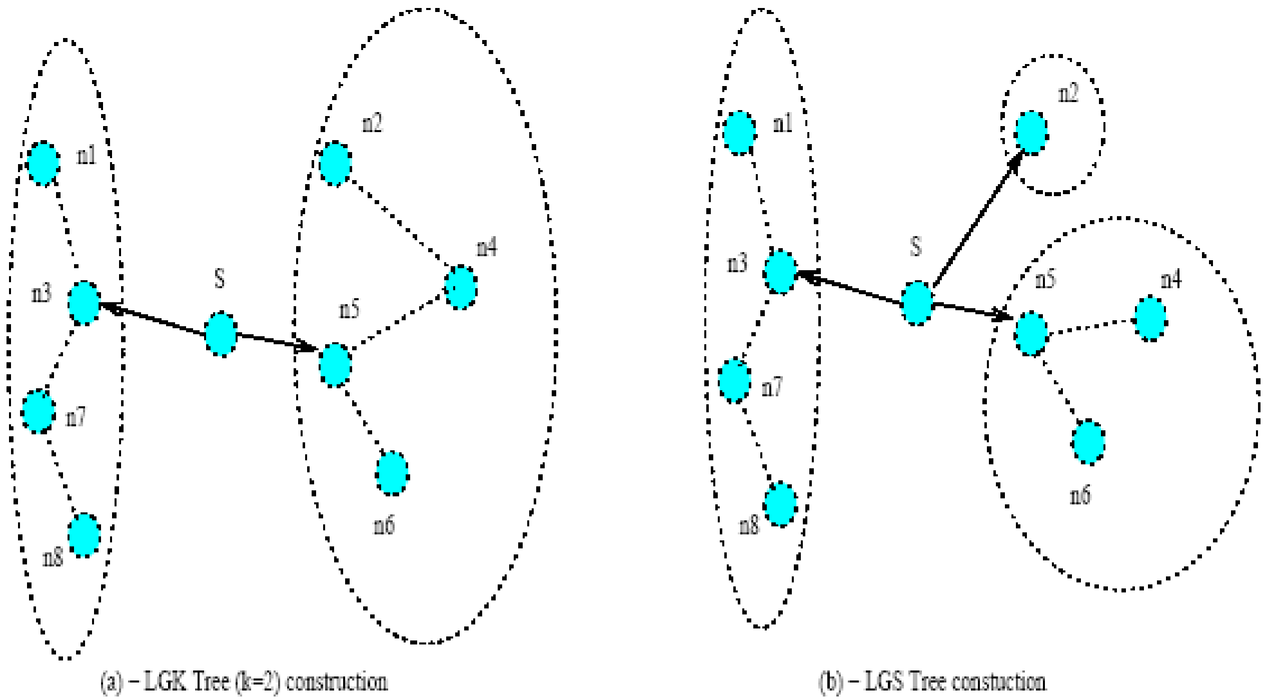
- **Lightweight Adaptive Multicast (LAM)**
  - Draws on the Core-Based Tree (CBT) protocol and the TORA unicast routing algorithm
  - Each multicast group initialized and maintained by a multicast server, or core
  - Any node which wants to communicate with a specific multicast group can query the directory server
  - It is more efficient due to elimination of duplicated control functionality between different protocol layers
  - LAM builds a group-shared multicast routing tree for each multicast group centered at the CORE
  - A multicast tree is source-initiated and group-shared and nodes in LAM maintain two variable, POTENTIAL-PARENT and PARENT, and two lists POTENTIAL-CHILD-LIST and CHILD-LIST
  - These potential data objects are used when the node is in a "join" or "rejoin" waiting state
  - LAM is based on CBT approach to build the multicast delivery tree
  - With one CORE for a group, LAM is not very robust

Small Group Multicast

- **Location Guided Tree Construction Algorithm for Small Group Multicast**
  - **This is a small group multicast schemes based on packet encapsulation**
  - **It builds an overlay multicast packet distribution tree on top of the underlying unicast routing protocol**
  - **Based on two types of tree: location-guided k-array (LGK) tree and a location-guided Steiner (LGS) tree**
  - **Geometric location information of the destination nodes is utilized to construct the packet distribution tree without knowing the global topology of the network**
  - **Protocol also supports an optimization mechanism through route caching**
  - **In LGK tree approach, the sender first selects nearest k destinations as children nodes**
  - **The sender then groups the rest of the nodes to its k children as per the closeness to geometric proximity**
  - **Once the group nodes are mapped to its corresponding child nodes, the sender forwards a copy of the encapsulated packet to each of the k children, with its corresponding subtree as destinations**
  - **Process stops when an in-coming packet has an empty destination list**

Location Guided Tree Construction

- **Location Guided Tree Construction Algorithm for Small Group Multicast**

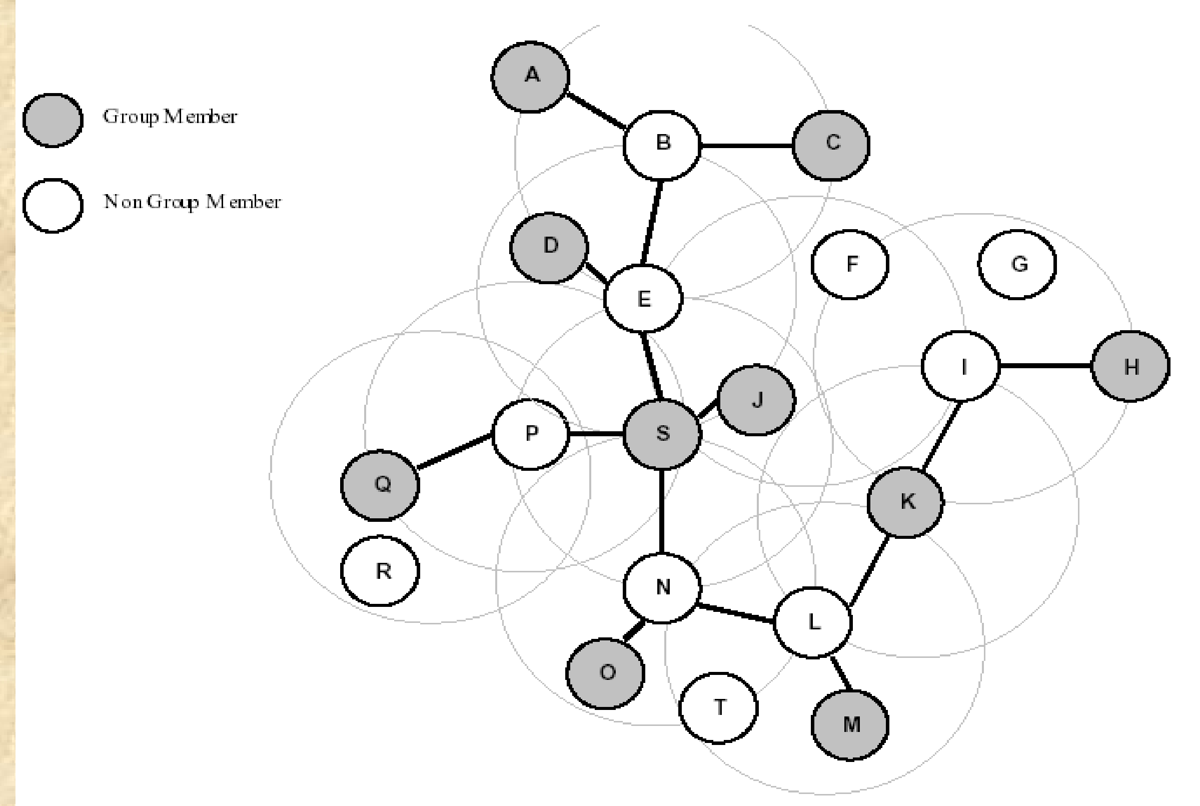


Zone Routing based Multicast

- *Multicast Zone Routing*
  - Takes into consideration the hierarchical structure used by the ZRP unicast routing protocol
  - Network is partitioned into zones
  - Each node computes its own zone, determined by nodes lieing within a certain radius of the node
  - ZRP is described as a hybrid approach between the proactive and reactive routing protocols
  - Routing is proactive inside the zones and reactive between the zones
  - To create a zone, a MZR node A broadcasts an ADVERTISEMENT message with a time-to-live (TTL) equal to a pre-configured ZONE-RADIUS
  - Node B within the zone radius decrements the TTL and forwards the message if appropriate
  - Node B makes an entry in its routing table for node A, with the last hop of the ADVERTISEMENT message as the next hop towards destination
  - Nodes ZONE-RADIUS hops away from node A become border nodes, and serve as a gateway between node A's zone and the rest of the network
  - MZR begins its search within the zone before extending outward
  - A source wants to start sending multicast traffic, it initiates the construction of a multicast tree
  - A TREE-CREATE-ACK packet is sent back to the source and intermediate nodes mark in their routing tables the last hop of the TREE-CREATE-ACK as a downstream node

Multicast Zone Routing

- Border node unicasts a TREE-CREATE-ACK to the multicast source to create a link between the border node and the source
- This sequence continues until every node in the network receives a TREE-CREATE message
- Routes in MZR are updated through the use of TREE-REFRESH packets
- If a node on the multicast tree fails to receive a TREEREFRESH message after a certain time, it deletes its multicast entry
- TREE-REFRESH packets could be piggybacked on multicast data whenever possible



- MZR creates a source specific, on-demand multicast tree with a minimal amount of routing overhead
- Hierarchical approach of MZR does not conserve bandwidth during the initial TREE-CREATE flood

Source Specific Multicast Tree

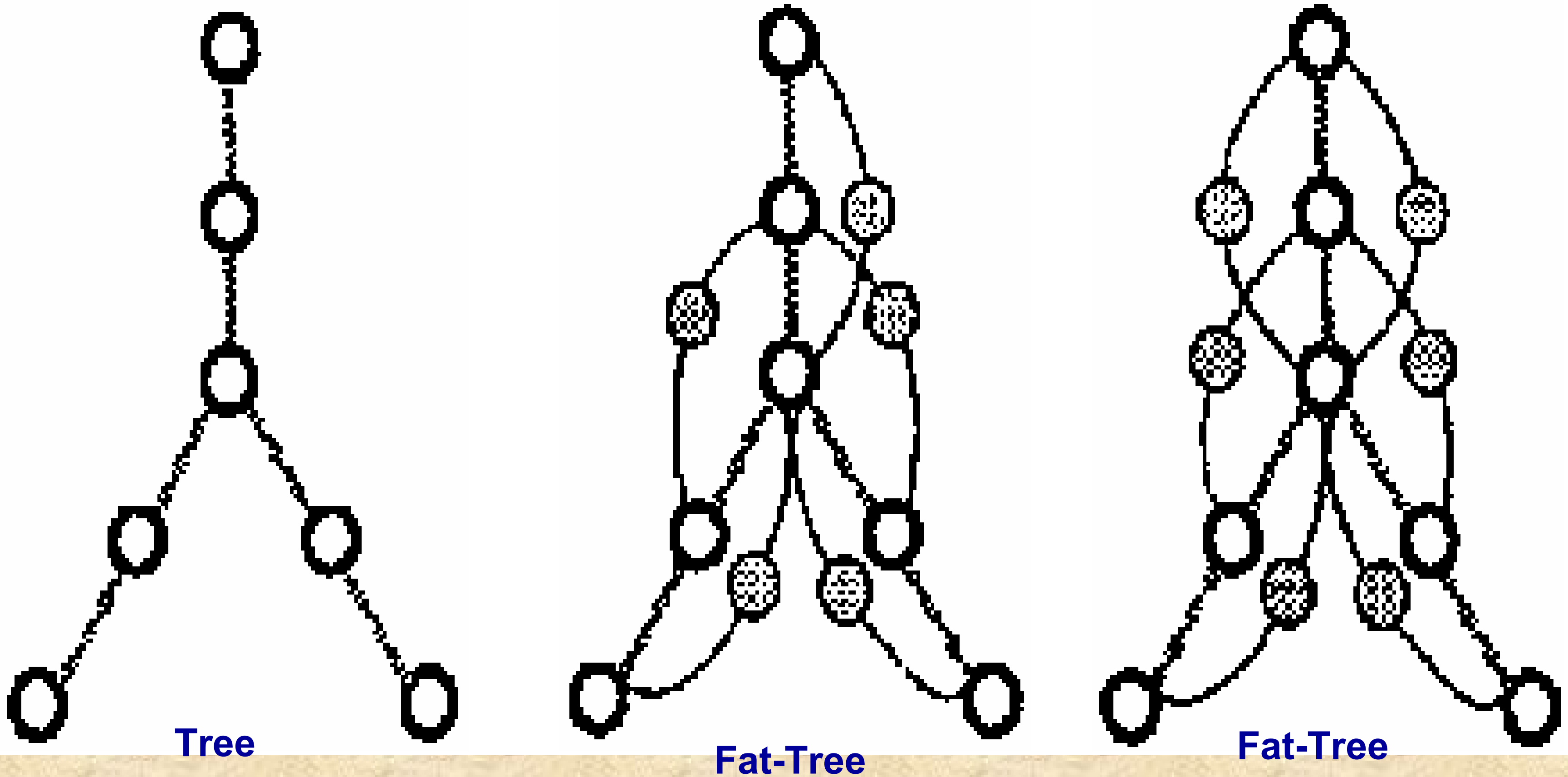
- *Multicast Optimized Link State Routing (MOLSR)*
  - MOLSR creates a source specific multicast tree
  - MOLSR is dependent on OLSR as unicast routing algorithm
  - Routers periodically advertise their ability to route and build multicast routes
  - MOLSR nodes can calculate shortest path routes to every potential multicast source
  - This is done in the same manner seen in OLSR, except that now the routes consist entirely of multicast-capable OLSR routers
  - Multicast routes are built in a backward manner similar to the method used in MZR
  - A source that wants to send multicast traffic advertises its intentions by broadcasting a SOURCE_CLAIM message to every node in the network
  - A multicast source periodically sends a SOURCE_CLAIM message to every node in the network for two reasons
  - First, it informs multicast receivers that the source is still sending data
  - Second, it allows unattached hosts to join the multicast group

Other Protocols

- The Associativity-Based Ad Hoc Multicast (ABAM)
  - This is an on-demand source-initiated multicast routing protocol
  - A multicast tree is built for each multicast group based on association stability
  - The link status of each node is monitored by its neighbors
  - ABAM deals with the network mobility on different levels according to varying mobility effects: branch repair when the receiver moves, sub-tree repair when a branching node moves, and full tree level repair when the source node moves
- On-demand Location-Aware Multicast (OLAM) protocol
  - OLAM assumes each node to be equipped with GPS device
  - Each node can process and take a snapshot of the network topology and make up a multicast tree (minimum spanning tree)
  - This protocol does not use any distributed data structures or ad hoc routing protocol as foundation and full tree level repair when the source node moves
- Adaptive Demand-Driven Multicast Routing (ADMR)
  - A protocol that attempts to reduce non-on-demand components
  - ADMR uses *tree flood* to enable packets to be forwarded following variant branches in the multicast tree
  - A multicast packet in ADMR floods within the multicast distribution tree only towards the group's receivers
- The Spiral-fat-tree-based On-demand Multicast (SOM) protocol
  - A spiral fat tree is built as the multicast tree to increase the stability of the tree structure
  - By using link redundancy of the fat tree, failed links will be easily replaced.

Spiral-fat-tree-based On-demand Multicast (SOM) protocol

A spiral fat tree is built to increase the stability of the tree structure



Mesh based Approach

- Mesh-based multicast protocols may have multiple paths between any source and receiver pairs
- Mesh-based protocols seem to outperform tree-based proposals due to availability of alternative paths
- A mesh has increased data-forwarding overhead
- The redundant forwarding consumes more bandwidth
- The probability of collisions is higher when a larger number of packets are generated

Mesh based Approach

- **On-Demand Multicast Routing Protocol**
- **Core-Assisted Mesh Protocol**
- **Forwarding Group Multicast Protocol**
- **Other Protocols**

On-Demand Multicast Routing Protocol

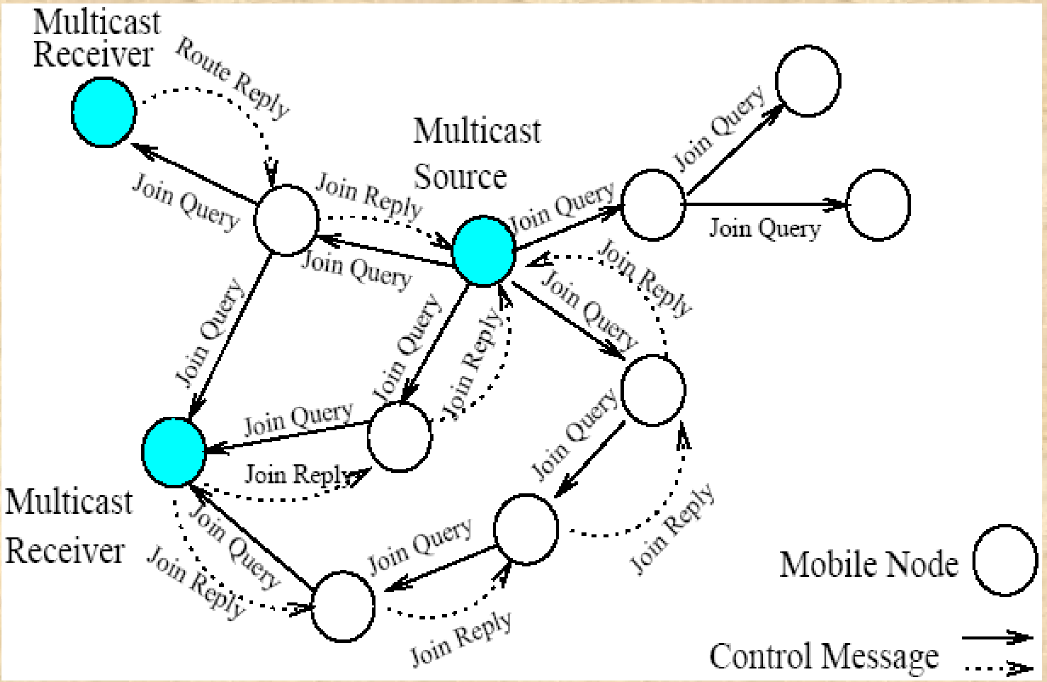
- Mesh-based protocol employing a forwarding group concept
- Only a subset of nodes forwards the multicast packets
- A soft state approach is taken in ODMRP to maintain multicast group members
- No explicit control message is required to leave the group
- The group membership and multicast routes are established and updated by the source on demand
- If no route to the multicast group, a multicast source broadcasts a Join-Query control packet to the entire network
- This Join-Query packet is periodically broadcasted to refresh the membership information and updates routes

On-Demand Multicast Routing Protocol

- After establishing a forwarding group and route construction process, a source can multicast packets to receivers via selected routes and forwarding groups

- To leave the group, source simply stops sending Join-Query packets

- If a receiver no longer wants to receive from a particular multicast group, it does not send the Join-Reply for that group



Core-Assisted Mesh Protocol

- Supports multicasting by creating a shared mesh for each multicast group
- Meshes thus created, helps in maintaining the connectivity to the multicast users, even in case of node mobility
- It borrows concepts from CBT, but the core nodes are used for control traffic needed to join multicast groups
- Assumes a mapping service by building and maintaining the multicast mesh
- Nodes are classified as: simplex, duplex and non-member
- CAMP uses a receiver-initiated method for routers to join a multicast group
- CAMP ensures the mesh to contain all reverse shortest paths between a source and the recipients

Mesh based Approach

- Forwarding Group Multicast Protocol
  - Can be viewed as flooding with “limited scope”
  - Flooding is contained within a selected forwarding group (FG) nodes
  - Makes innovative use of flags and an associated timer to forward multicast packets
  - Uses two approaches to elect and maintain FG of forwarding nodes: FGMP-RA (Receiver Advertising) and FGMP-SA (Sender Advertising)

Mesh based Approach

Other Protocols

- A local routing scheme is proposed in the Neighbor Supporting ad hoc Multicast routing Protocol (NSMP)
- Two types of route discovery: flooding route discovery and local route discovery
- Intelligent On-Demand Multicast Routing Protocol (IOD-MRP) is a modified version of CAMP by employing an on-demand receiver initiated procedure to dynamically build routes and maintain multicast group membership instead of using cores
- Source Routing-based Multicast Protocol (SRMP) applies the source routing mechanism defined by the DSR unicast protocol in a modified manner, decreasing the size of the packet header
- Protocol operates in a loop-free manner, minimizing channel overhead and making efficient use of network resources

Stateless Approaches

- **Differential Destination Multicast**
  - Meant for small-multicast groups operating in dynamic networks of any size
  - DDM lets source to control multicast group membership
  - Each node along the forwarding path remembers the destinations to which the packet has been forwarded last time and its next hop information
  - At each node, there is one Forwarding Set (FS) for each multicast session
  - The nodes also maintain a Direction Set (DS) to record the particular next hop to which multicast destination data are forwarded
  - Source node, FS contains the same set of nodes as the multicast Member List (ML)
  - In the intermediate nodes, the FS is the union of several subsets based on the data stream received from upstream neighbors
  - Associated with each set FS_k, there is a sequence number SEQ(FS_k) which is used to record the last DDM Block Sequence Number seen in a received DDM data packet from an upstream neighbor k

Stateless Approaches

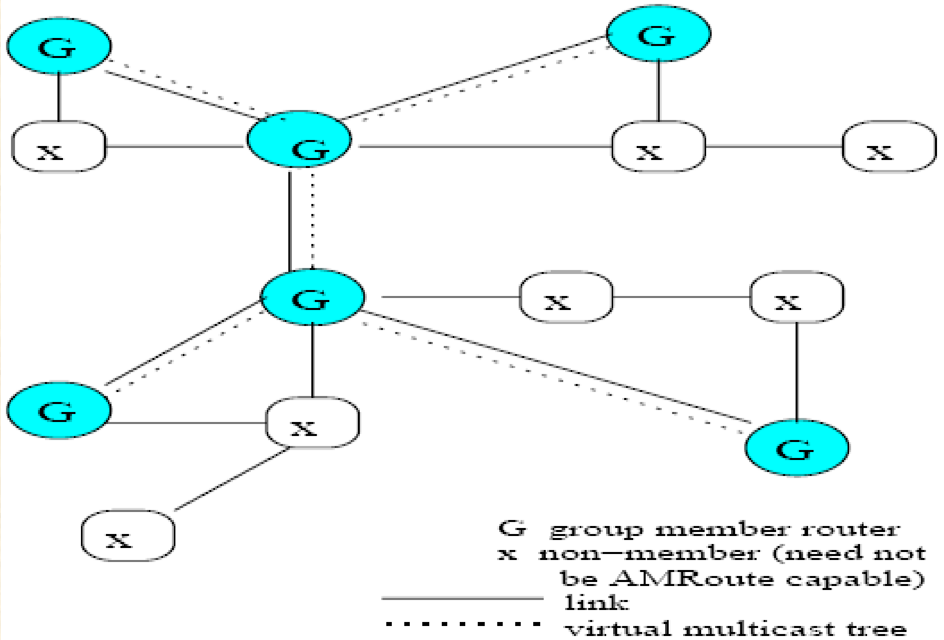
- **DSR Simple Multicast and Broadcast Protocol**
  - **Designed to provide multicast and broadcast functionality**
  - **It utilizes the Route Discovery mechanism defined by the DSR unicast protocol to flood the data packets in the network**
  - **It can be implemented as a stand-alone protocol**
  - **In fact, it does not rely on unicast routing to operate**
  - **If DSR has already been implemented on the network, minor modifications are required to enable this protocol**

Hybrid Approaches

- **Ad hoc Multicast Routing Protocol**
  - **Creates a bi-directional, shared tree by using only group senders and receivers as tree nodes for data distribution**
  - **The protocol has two main components: mesh creation and tree setup**
  - **The mesh creation identifies and designates certain nodes as logical cores and these are responsible for initiating the signaling operation and maintaining the multicast tree to the rest of the group members**
  - **A non-core node only responds to messages from the core nodes and serves as a passive agent**
  - **The selection of logical core in AMRoute is dynamic and can migrate to any other member node, depending on the network dynamics and the group membership**
  - **AMRoute does not address network dynamics and assumes the underlying unicast protocol to take care**

Hybrid Approaches

- **Ad hoc Multicast Routing Protocol**



Hybrid Approaches

- Multicast Core-Extraction Distributed Ad Hoc Routing
  - The main idea is to provide the efficiency of the tree-based forwarding protocols and robustness of mesh-based protocols by combining these two approaches
  - The infrastructure is robust and data forwarding occurs at minimum height trees
- Mobility-based Hybrid Multicast Routing
  - Designed to provide multicast and broadcast functionality
  - Built on top of the mobility-based clustering infrastructure
  - The structure is hierarchical in nature
  - The mobility and positioning information is provided via a GPS for each node
  - Cores are employed in both AMRoute and MCEDAR, as well as in many tree and mesh multicast algorithms

Comparison of Multicast

Protocol	Topology	Loop Free	Dependence on Unicast Protocol	Periodic Message	Control Packet Flooding Done/Required
Flooding	Mesh	Yes	No	No	No
AMRoute	Hybrid	No	Yes	Yes	Yes
AMRIS	Tree	Yes	No	Yes	Yes
MAODV	Tree	Yes	Yes	Yes	Yes
LAM	Tree	Yes	Yes	No	No
LGT-Based	Tree	Yes	No	Yes	No
ODMRP	Mesh	Yes	No	Yes	Yes
CAMP	Mesh	Yes	Yes	Yes	No
DDM	Stateless Tree	Yes	No	Yes	No
FGMP-RA	Mesh	Yes	Yes	Yes	Yes
FGMP-SA	Mesh	Yes	No	Yes	Yes
MCEDAR	Hybrid	Yes	Yes	Yes	Yes

Geocasting

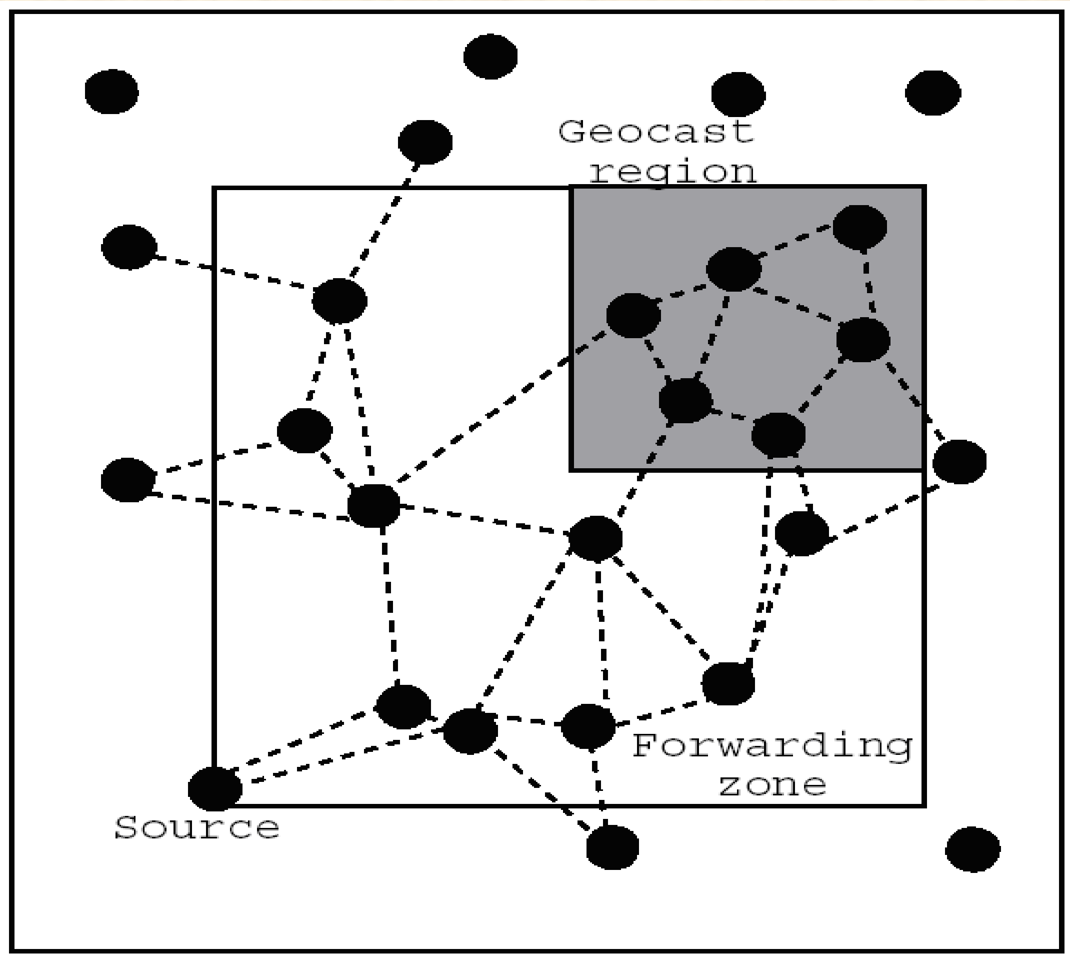
- **Geocasting is a variant of the conventional multicasting problem**
- **Group members are within a specified geographical region**
- **Whenever a node in the geocast region receives a geocast packet, it floods the geocast packet to all its neighbors**
- **A geocast protocol works if at least one node in the geocast region receives the geocast packet**
- **Protocols use a *jitter* technique in order to avoid two packets colliding with each other by a broadcast**
- **Existing geocast protocols divided into two categories: *data-transmission oriented protocols* and *routing creation oriented protocols***
- **The difference is how they transmit information from a source to one or more nodes in the geocast region**

Data-Transmission Oriented Geocast Routing Protocols

- **Location-Based Multicast**
  - **Extends the LAR unicast routing algorithm for geocasting**
  - **Utilize location information to improve the performance of a unicast routing protocol**
  - **The goal is to decrease delivery overhead of geocast packets by reducing the forwarding space for geocast packets, while maintaining accuracy of data delivery**
  - **The algorithm is based upon a flooding approach while a node determines whether to forward a geocast packet further via one of two schemes**

LBM Scheme 1

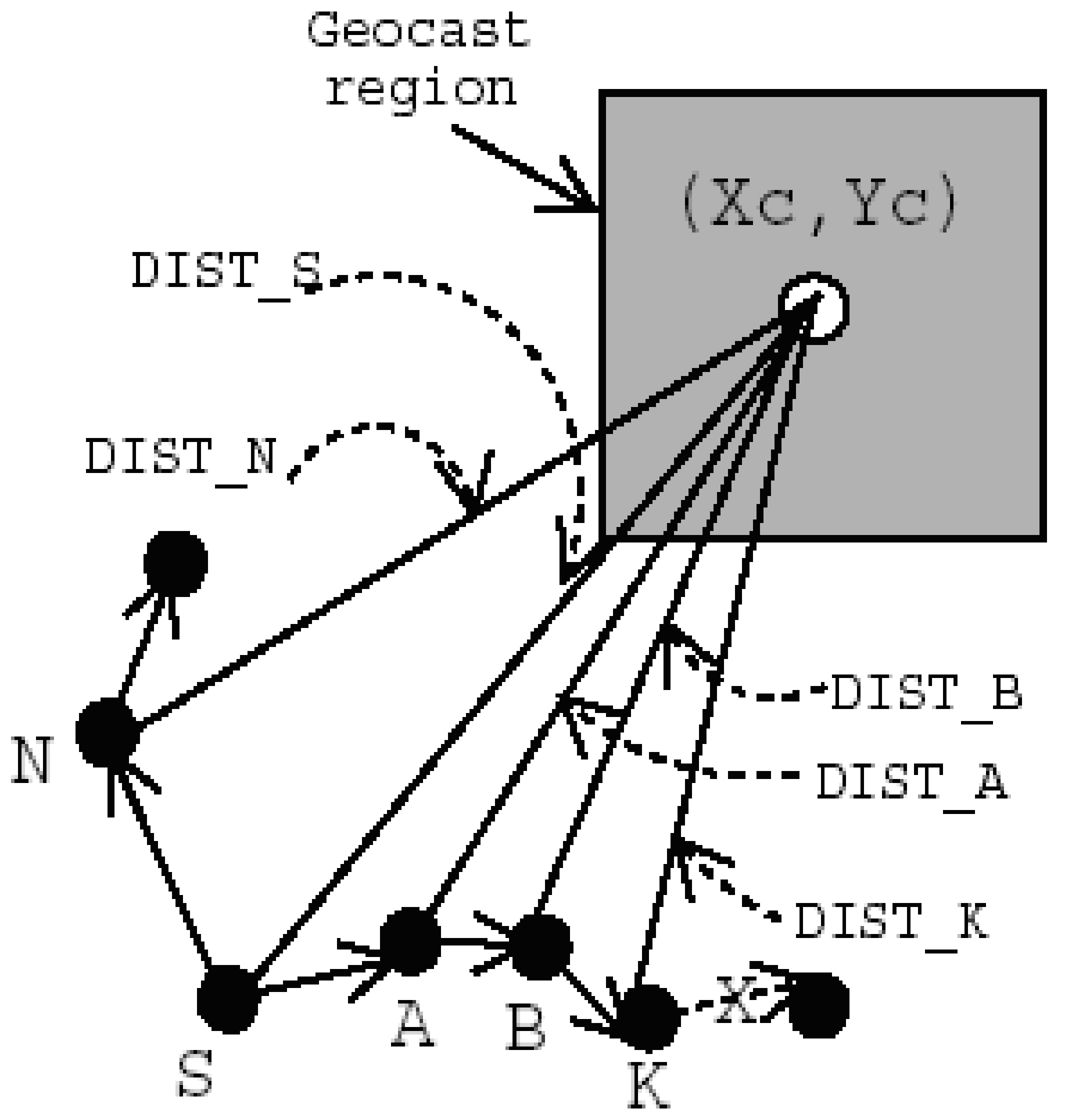
- A node receives a geocast packet, it forwards the packet to its neighbors if it is within a *forwarding zone*
- The size of the forwarding zone depends on (i) the size of the geocast region and (ii) the location of the sender
- A parameter d provides additional control on the size of the forwarding zone



Box forwarding zone: Rectangle covering source and the forwarding zone

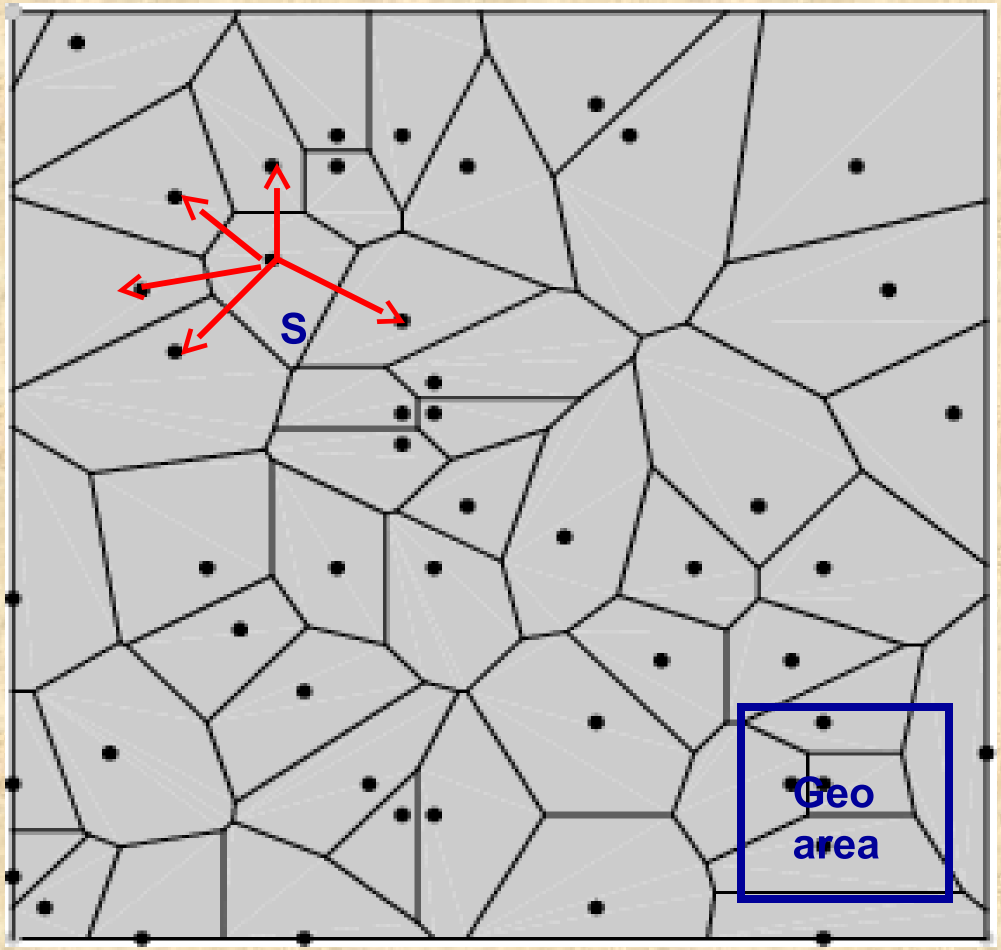
LBM Scheme 2

- Does not have a forwarding zone explicitly
- Forwarding is based on the position of the sender node and the position of the geocast region
- Node B forwards a geocast packet from node A if node B is "at least d closer" to the center of the geocast region
- Node K will, however, discard a geocast packet transmitted by node B



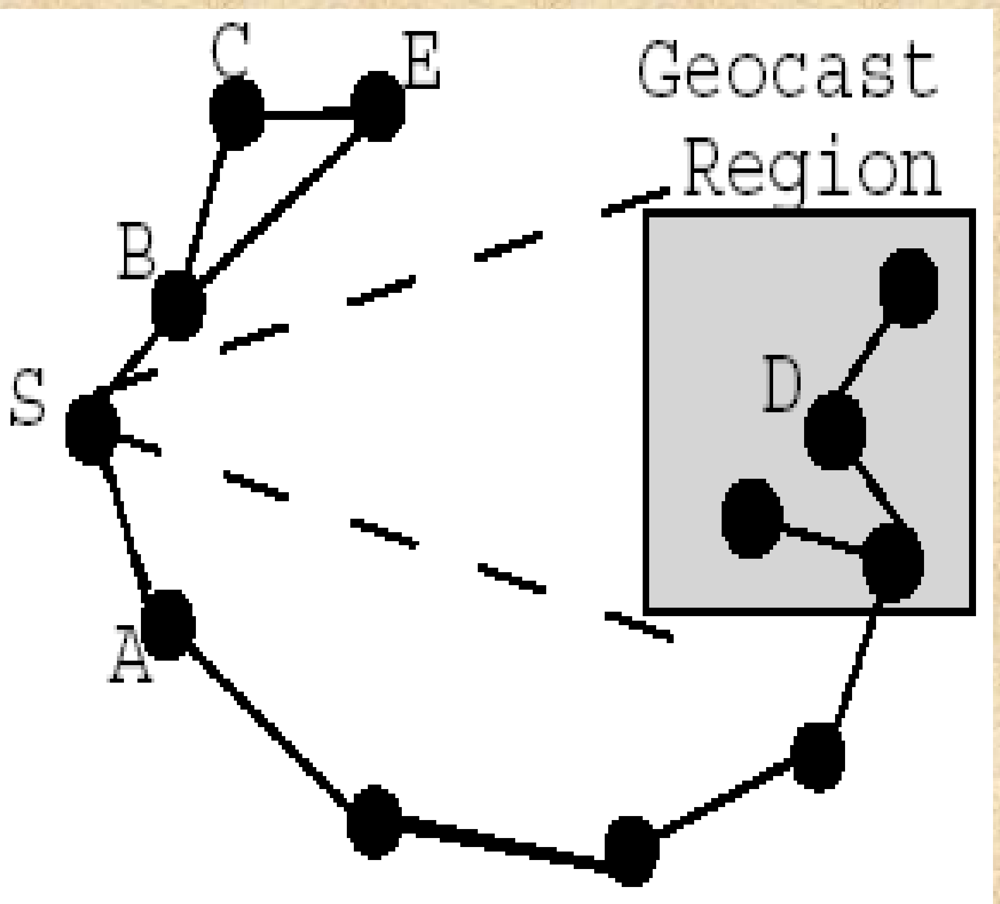
Voronoi Diagram

The Voronoi diagram partitions the area in to a set of convex polygons such that all polygon edges are equidistance



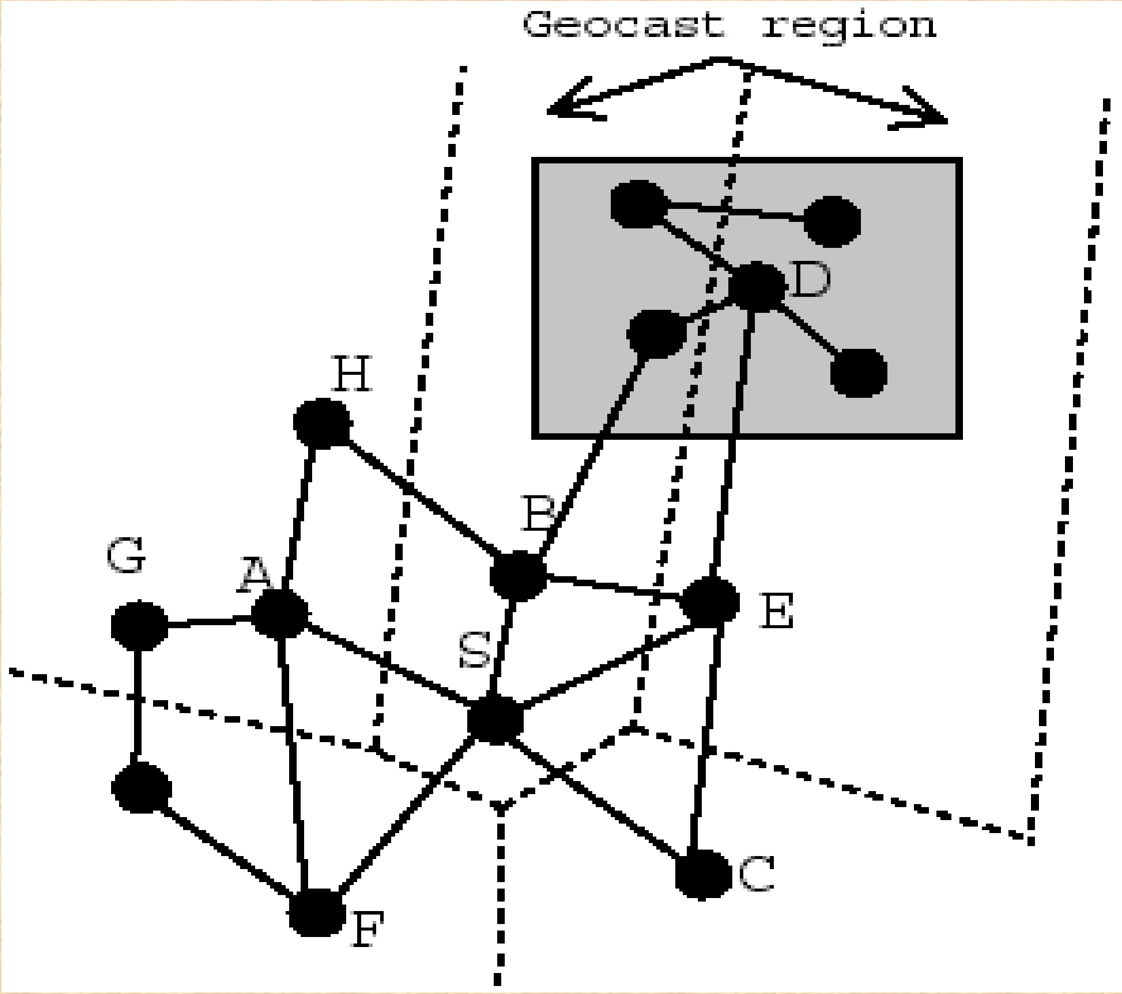
Voronoi Diagram Based Geocasting

- The goal is to enhance the success rate and decrease the hop count and flooding rate
- The forwarding zone defined in LMB may be a partitioned network between the source node and the geocast region



Voronoi Diagram and Request Zone

- Neighbors that are closest in the direction of the destination forms the forwarding zone
- Can be implemented with a *Voronoi diagram* for a set of nodes in a given node's neighborhood
- VDG reduces the flooding rates of LBM Scheme 1, as fewer packets should be transmitted
- VDG may offer little improvement over LBM Scheme

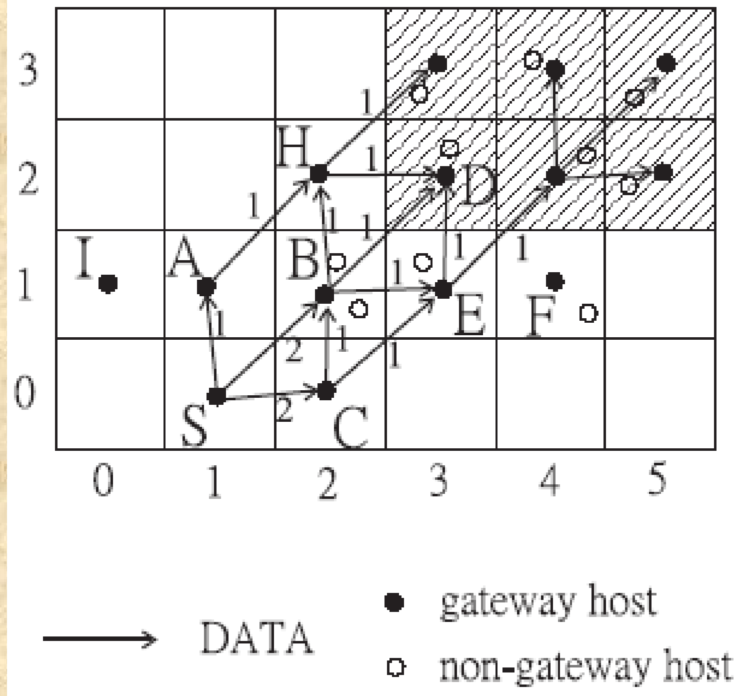


GeoGRID

- **GeoGRID protocol uses location information in defining forwarding zone and elects a special host in each grid area responsible for forwarding geocast packets**
- **The forwarding zone in LBM incurs unnecessary packet transmissions**
- **A tree-based solution is prohibitive in terms of control overhead**
- **GeoGRID partitions the geographic area into two-dimensional logical grids of size *d X d***
- **Two schemes on how to send geocast packets in GeoGRID: *Flooding-Based GeoGRID* and *Ticket-Based GeoGRID*.**

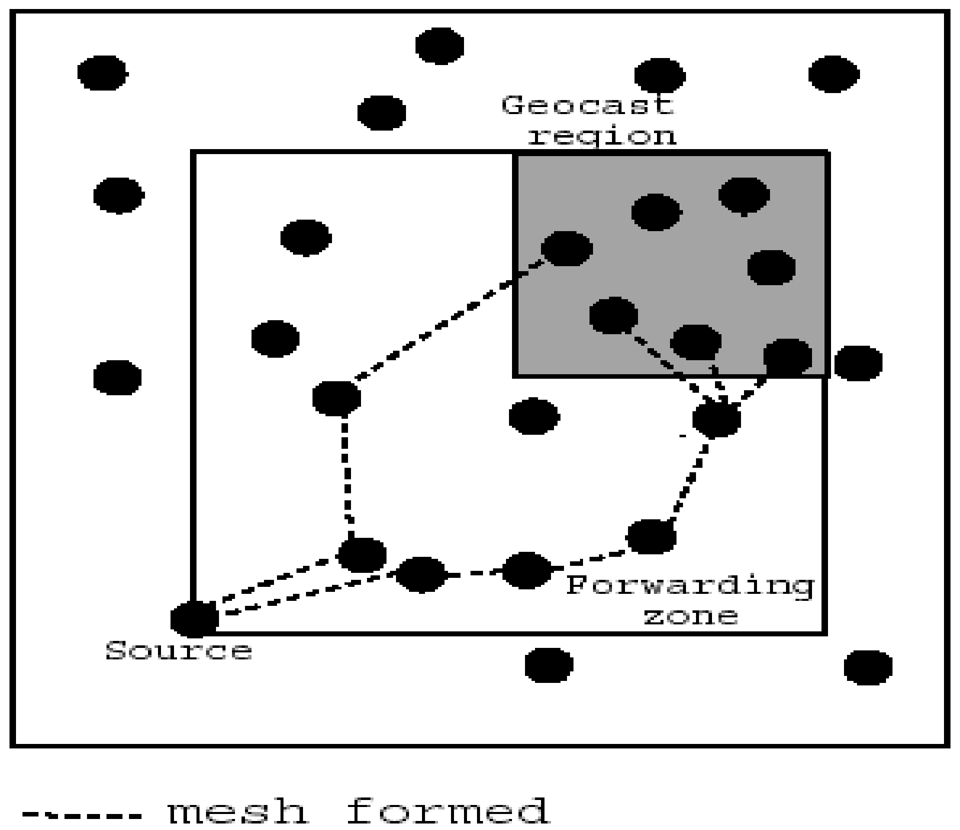
Flooding-Based GeoGRID

- **Only gateways in every grid within the forwarding zone rebroadcast the received geocast packets**
- **A total of *m* + *n* tickets are created by the source if the geocast region is a rectangle of *m X n* grid**



Flooding-Based GeoGRID

- Route Creation Oriented
  - GeoTORA: reduce the overhead of transmitting geocast packets via flooding techniques, while maintaining high accuracy
  - Mesh-based Geocast Routing Protocol: uses a mesh for geocasting to provide redundant paths between source and group members



Conclusions and Future Directions

- Scalability
- Applications for broadcast, multicast, and geocast over MANETs
- QoS
- Address configuration
- Security
- Power control